



# The Wide Field Infrared Survey Telescope (WFIRST)

Alex Merson

Jet Propulsion Laboratory/California Institute of Technology/IPAC  
(on behalf of the WFIRST Cosmology with the HLS SIT)

#NASAWFIRST Government Sponsorship Acknowledged. The decision to implement the WFIRST mission will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only. Copyright 2018. All rights reserved.



STScI | SPACE TELESCOPE  
SCIENCE INSTITUTE



# HLS Science Investigation Team Members

Ivano Baronchelli (Caltech/IPAC)

Rachel Bean (Cornell)

Andrew Benson (Carnegie)

Peter Capak (Caltech/IPAC)

Ami Choi (OSU)

**James Colbert (Caltech/IPAC)**

**Olivier Doré (JPL/Caltech, PI)**

Tim Eifler (JPL/Caltech)

Chen He Heinrich (JPL/Caltech)

Katrin Heitmann (ANL)

George Helou (Caltech/IPAC)

Shoubaneh Hemmati  
(IPAC/Caltech)

Shirley Ho (LBL)

Eric Huff (JPL)

Albert Izard (JPL)

Bhuvnesh Jain (Penn)

Mike Jarvis (Penn)

Alina Kiessling (JPL/Caltech)

Elisabeth Krause (Stanford)

**Chris Hirata (OSU,  
Weak lensing lead)**

Alexie Leauthaud (UCSC)

Robert Lupton (Princeton)

Niall MacCrann (OSU)

Rachel Mandelbaum (CMU)

Elena Massara (LBL)

Dan Masters (JPL)

**Alex Merson (JPL/IPAC)**

Hironao Miyatake (JPL/Caltech)

Nikhil Padmanabhan (Yale)

Alice Pisani (Princeton)

Andres Plazas Malagon (JPL/Caltech)

Eduardo Rozo (U. Arizona)

Lado Samushia (U. Kansas)

Mike Seiffert (JPL/Caltech)

Charles Shapiro (JPL/Caltech)

Melanie Simet (UCR/JPL)

David Spergel (Princeton, CCA)

**Harry Teplitz (Caltech/IPAC)**

Michael Troxel (OSU)

Anja von der Linden  
(Stony Brook University)

**Yun Wang (Caltech/IPAC,  
Galaxy redshift survey lead)**

**David Weinberg (OSU,  
Galaxy clusters lead)**

Hao-Yi Wu (OSU)

Ying Zu (OSU)

~40 members

# HLS Science Investigation Team Members

Ivano Baronchelli (Caltech/IPAC)

**Rachel Bean (Cornell)**

Andrew Benson (Carnegie)

**Peter Capak (Caltech/IPAC)**

Ami Choi (OSU)

**James Colbert (Caltech/IPAC)**

**Olivier Doré (JPL/Caltech, PI)**

Tim Eifler (JPL/Caltech)

Chen He Heinrich (JPL/Caltech)

Katrin Heitmann (ANL)

**George Helou (Caltech/IPAC)**

Shoubaneh Hemmati  
(IPAC/Caltech)

**Shirley Ho (LBL)**

**Eric Huff (JPL)**

**Albert Izard (JPL)**

**Bhuvnesh Jain (Penn)**

Mike Jarvis (Penn)

**Alina Kiessling (JPL/Caltech)**

Elisabeth Krause (Stanford)

**Chris Hirata (OSU,  
Weak lensing lead)**

Alexie Leauthaud (UCSC)

**Robert Lupton (Princeton)**

Niall MacCrann (OSU)

**Rachel Mandelbaum (CMU)**

Elena Massara (LBL)

**Dan Masters (JPL)**

**Alex Merson (JPL/IPAC)**

Hironao Miyatake (JPL/Caltech)

**Nikhil Padmanabhan (Yale)**

Alice Pisani (Princeton)

Andres Plazas Malagon (JPL/Caltech)

Eduardo Rozo (U. Arizona)

**Lado Samushia (U. Kansas)**

**Mike Seiffert (JPL/Caltech)**

Charles Shapiro (JPL/Caltech)

Melanie Simet (UCR/JPL)

**David Spergel (Princeton, CCA)**

**Harry Teplitz (Caltech/IPAC)**

Michael Troxel (OSU)

Anja von der Linden  
(Stony Brook University)

**Yun Wang (Caltech/IPAC,  
Galaxy redshift survey lead)**

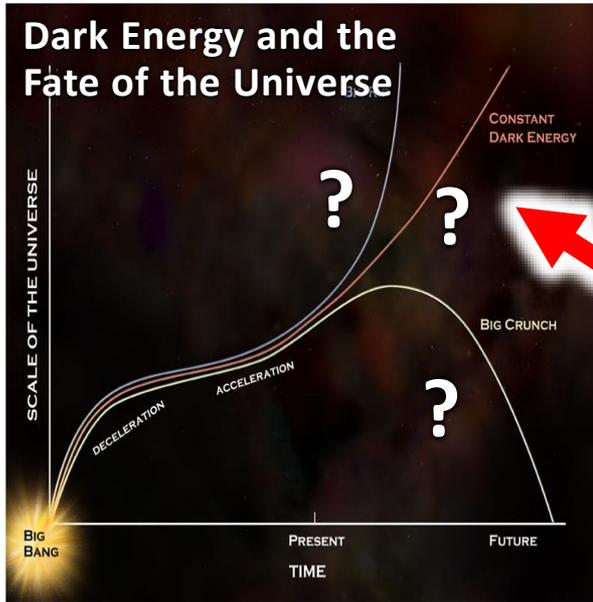
**David Weinberg (OSU,  
Galaxy clusters lead)**

Hao-Yi Wu (OSU)

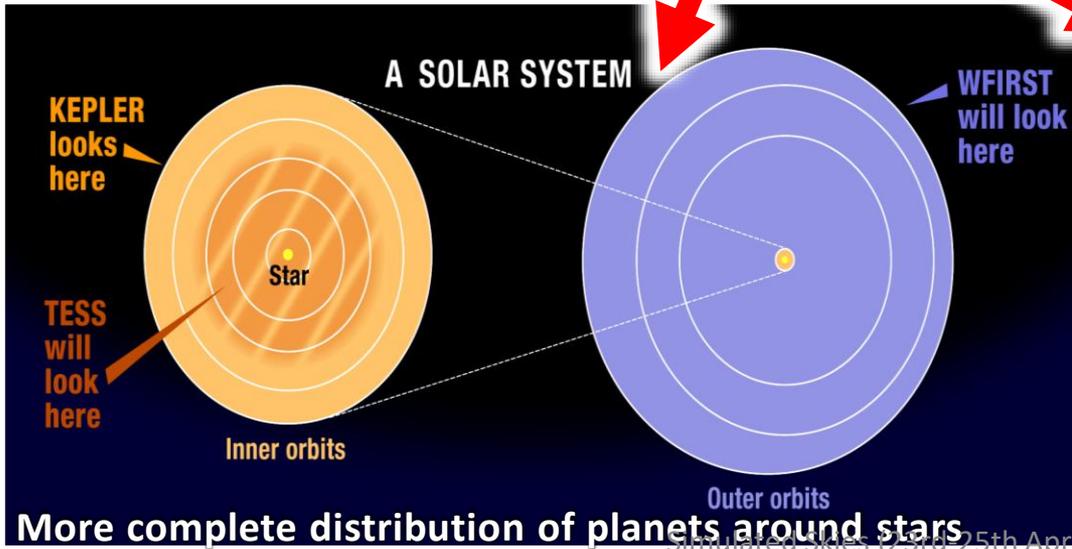
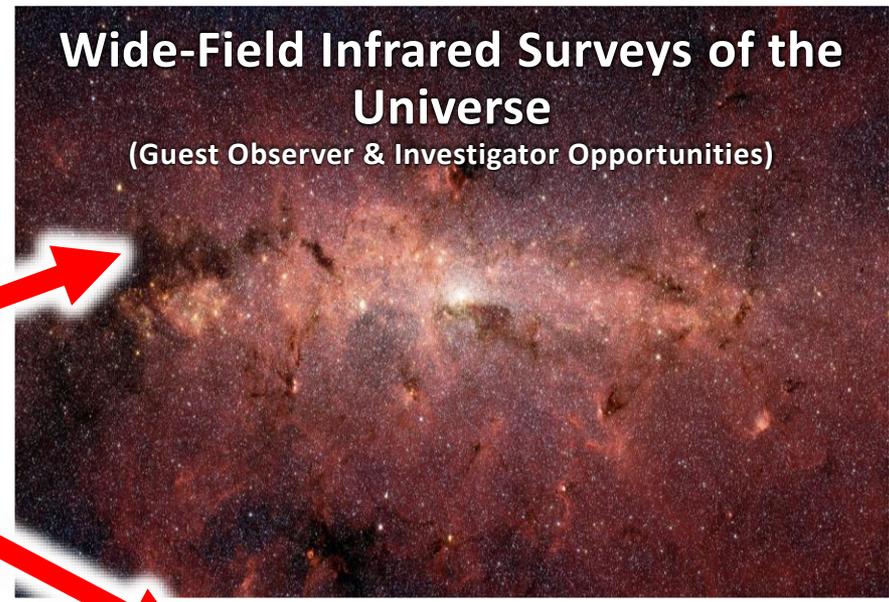
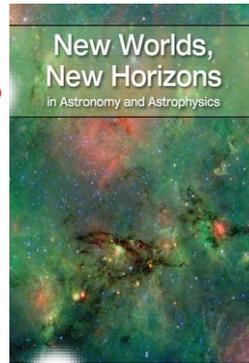
Ying Zu (OSU)

~22 also members of  
Euclid Consortium

# WFIRST Scientific Objectives



National Academy of Sciences 2010 Decadal Survey



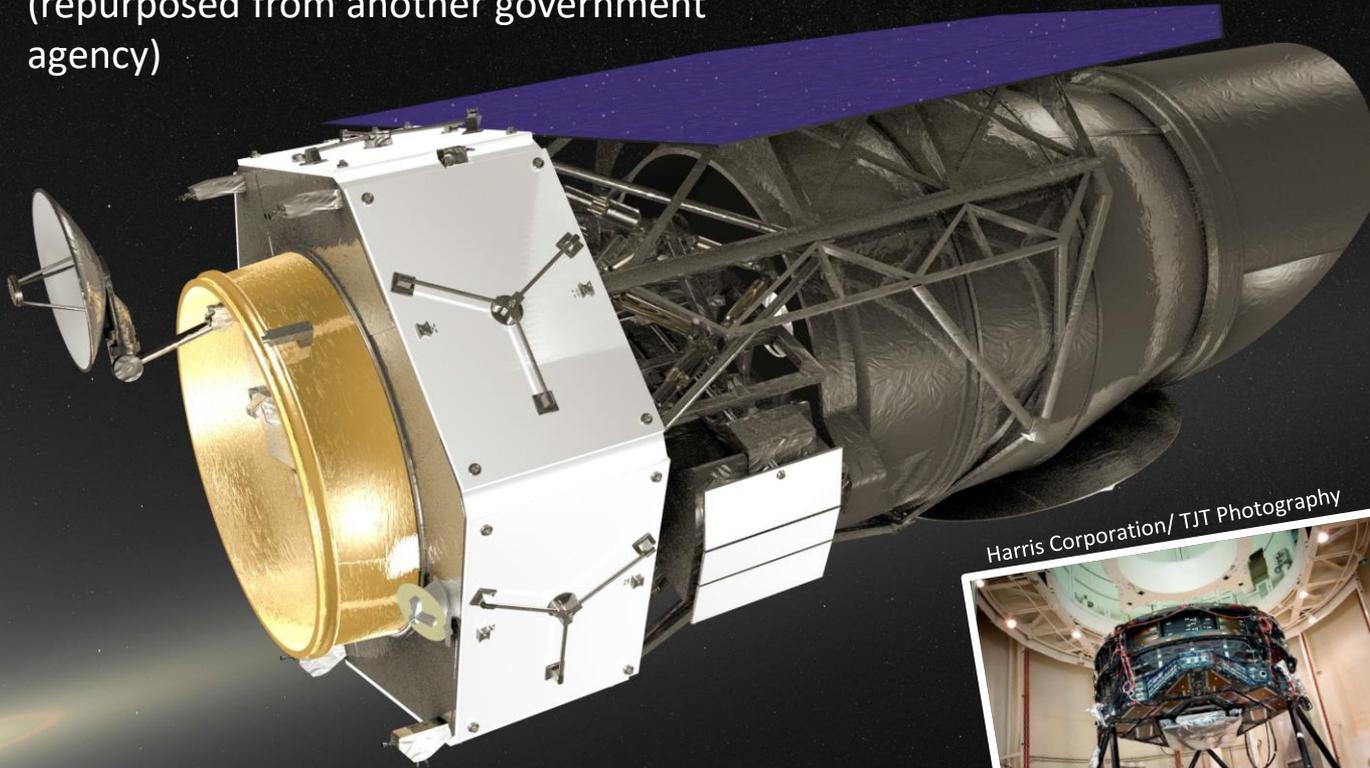
More complete distribution of planets around stars



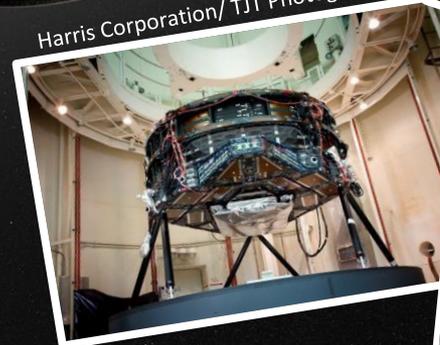
Simulated Skies (23rd-25th April 2018)

# WFIRST: the next NASA flagship mission

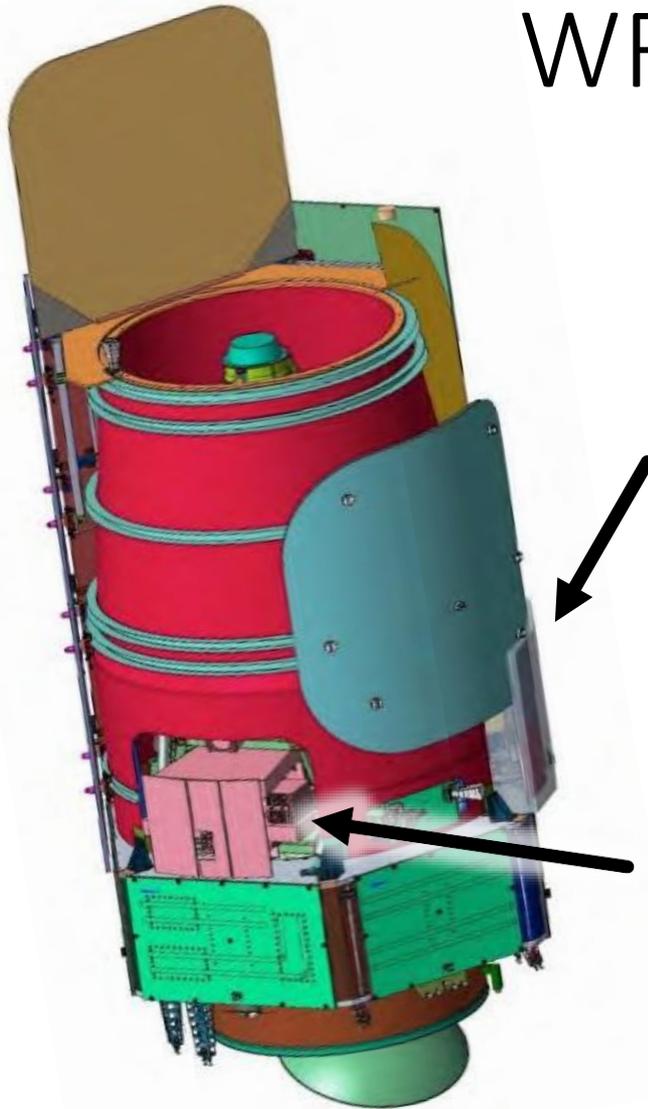
- Top priority for large space-based telescope.
- 2.4m Hubble-sized telescope (repurposed from another government agency)
- Dark energy and exoplanet mission with wide-field survey capabilities.
- Due for launch ~2025.



Harris Corporation/ TJT Photography



# WFIRST Instruments



## Wide Field Instrument

- Imaging & spectroscopy over 1000s sq.deg.
- Monitoring of SN and microlensing fields
- Near-IR filter imaging, grism + IFC spectroscopy
- 0.7-2.0  $\mu\text{m}$  (imaging),  $\sim 1.0\text{-}2.0 \mu\text{m}$  (spec.)
- 0.28  $\text{deg}^2$  FoV (100x Hubble and JWST FoV)
- 18 H4RG detectors (288 Mega pixels)

## Coronagraph (technology demonstration)

- Imaging and spectroscopy of exoplanets (Jupiter/Neptune-like exoplanets)
- Imaging of debris discs
- 430-970 nm (imaging), 600-970 nm (spec.)
- Planet/star flux ratio of  $10^{-9}$  (or better)
- Exoplanet imaging from 0.1 – 1.0 arcseconds

# WFIRST = wide field + high resolution

- Very large field of view  
( $0.8^\circ \times 0.4^\circ$ )
- High spatial resolution  
( $0.11''/\text{pixel}$ )

Hubble image quality  
over 100x more sky!

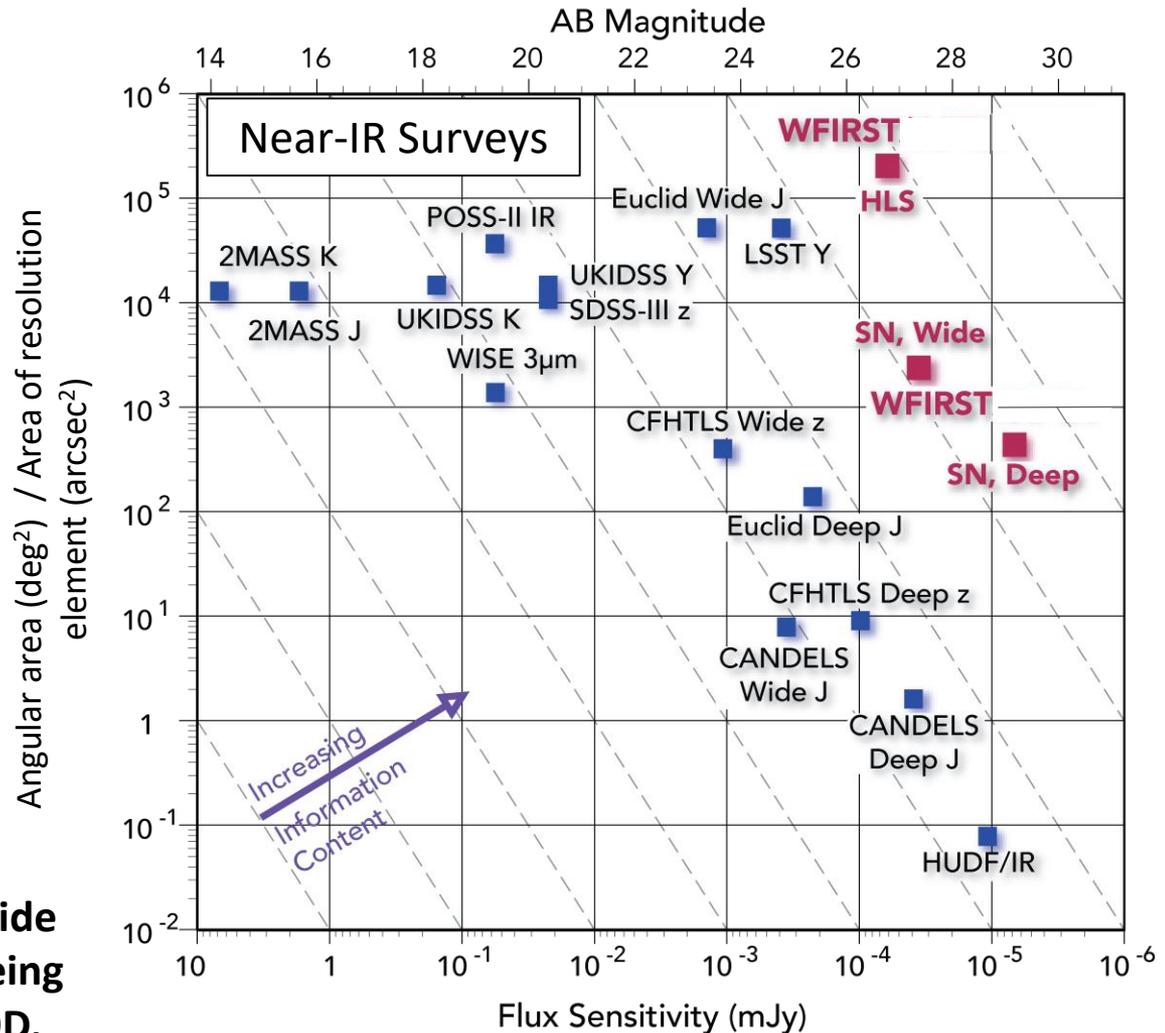
# WFIRST Surveys

Figure: wfirst.gsfc.nasa.gov

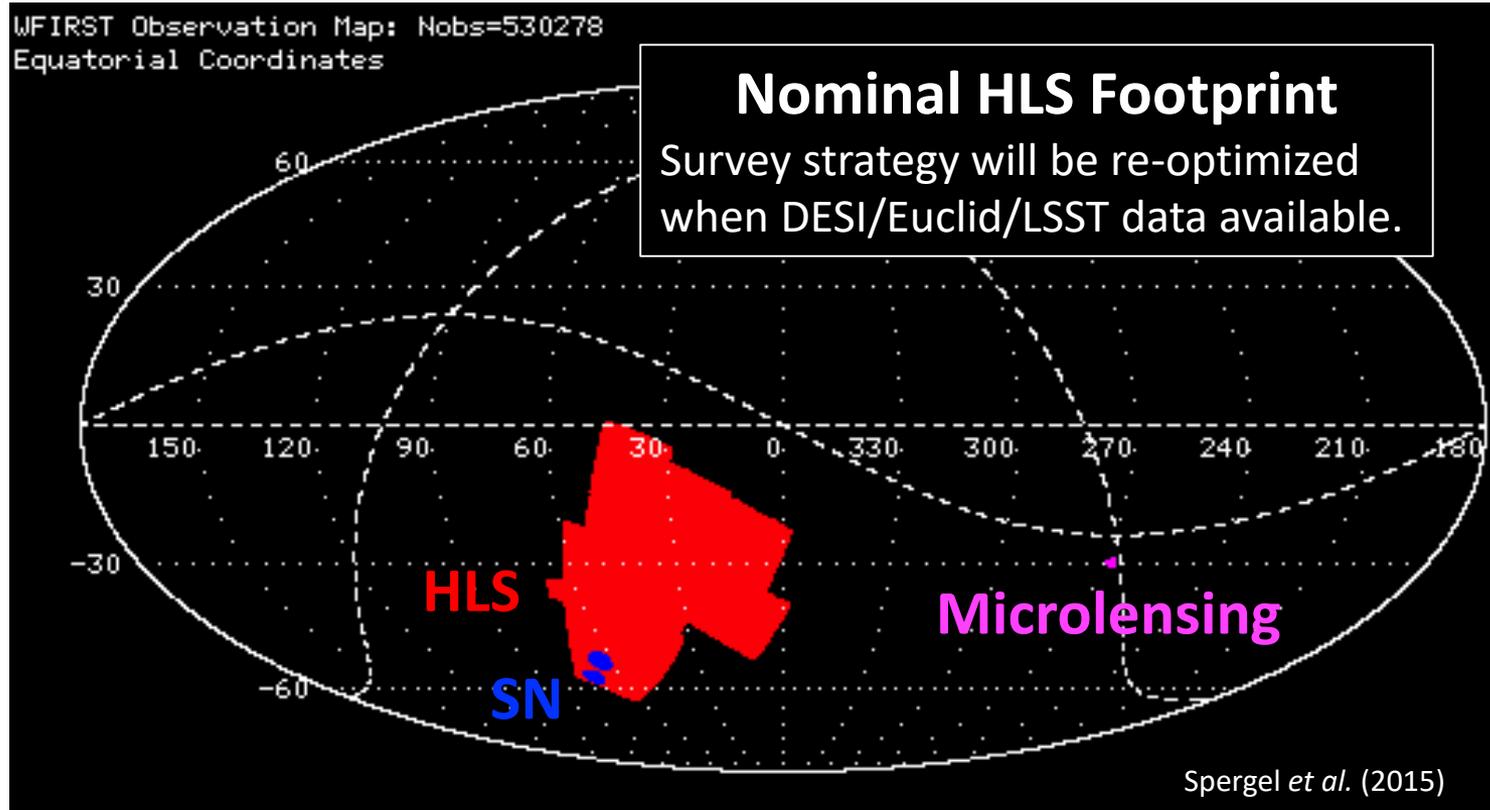
## 5 year nominal mission:

- High Latitude Survey (HLS) [1.5 years]
  - Imaging
  - Slitless spectroscopy
- SN monitoring [6 months]
- 25% GO Program (100% in extended mission)
- Coronagraph observations & technology demonstration [~1 year]
- Repeat observations of Galactic bulge (microlensing events) [~1 year]

**All data to be made public worldwide within few days of observations being taken, i.e. NO PROPRIETARY PERIOD.**

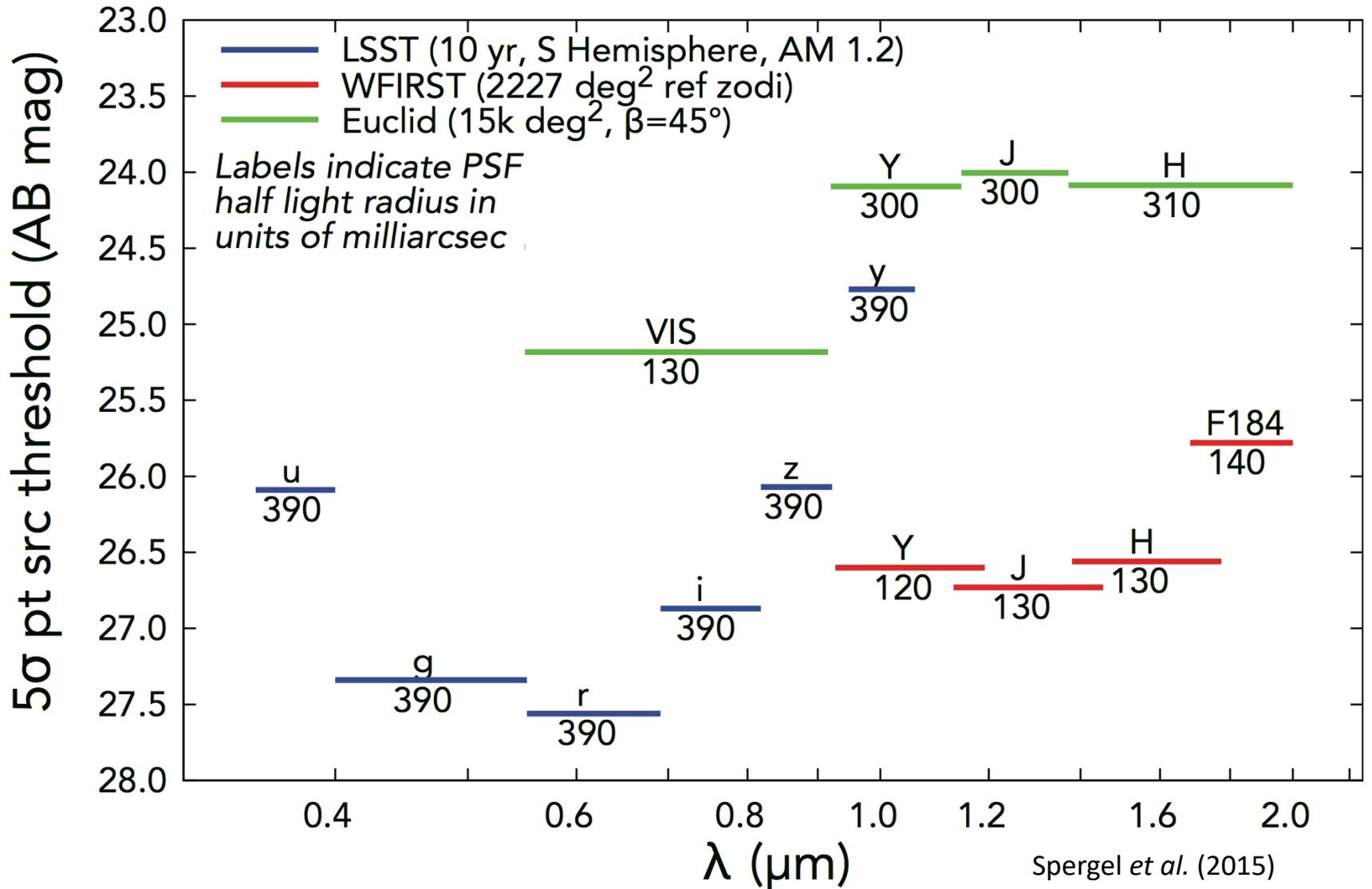


# WFIRST High Latitude Survey (HLS)



- Nominally 1.5yr over  $\sim 2,000 \text{ deg}^2$  in southern sky (c.f. Euclid:  $15,000 \text{ deg}^2$  over 6yr)
- Cosmological probes: (i) near-IR spectroscopic galaxy clustering (BAO+RSD)  
 $f > 1 \times 10^{-16} \text{ ergs/s/cm}^2$  (c.f. Euclid:  $2 \times 10^{-16} \text{ ergs/s/cm}^2$ )  
(ii) gravitational weak lensing shear measurements  
Y, J, H, F184 to AB  $\sim 26.5$  ( $5\sigma$  point src) (c.f. Euclid VIS AB  $\sim 24.5$ )

# Sensitivities of LSST, WFIRST, and Euclid



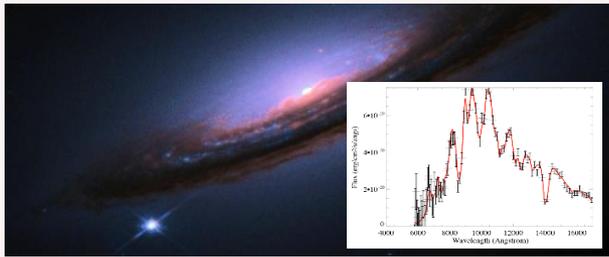
Spergel et al. (2015)

# WFIRST Dark Energy Science Outline

## Supernova Survey

wide, medium, & deep imaging  
+  
IFU spectroscopy  
-----  
2700 type Ia supernovae  
 $z = 0.1-1.7$

standard candle distances  
 $z < 1$  to 0.20% and  $z > 1$  to 0.34%



## High Latitude Survey

spectroscopic: galaxy redshifts

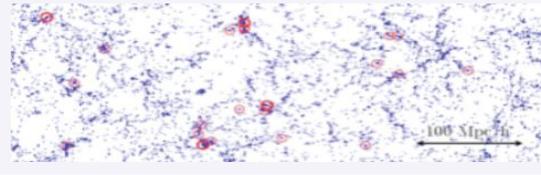
20 million H $\alpha$  galaxies,  $z = 1-2$   
1.4 million [OIII] galaxies,  $z = 2-3$

imaging: weak lensing shapes

380 million lensed galaxies  
40,000 massive clusters

standard ruler

distances	expansion rate
$z = 1-2$ to 0.5%	$z = 1-2$ to 0.9%
$z = 2-3$ to 1.3%	$z = 2-3$ to 2.1%



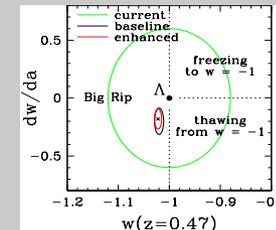
dark matter clustering

$z < 1$  to 0.21% (WL); 0.24% (CL)  
 $z > 1$  to 0.78% (WL); 0.88% (CL)  
1.1% (RSD)



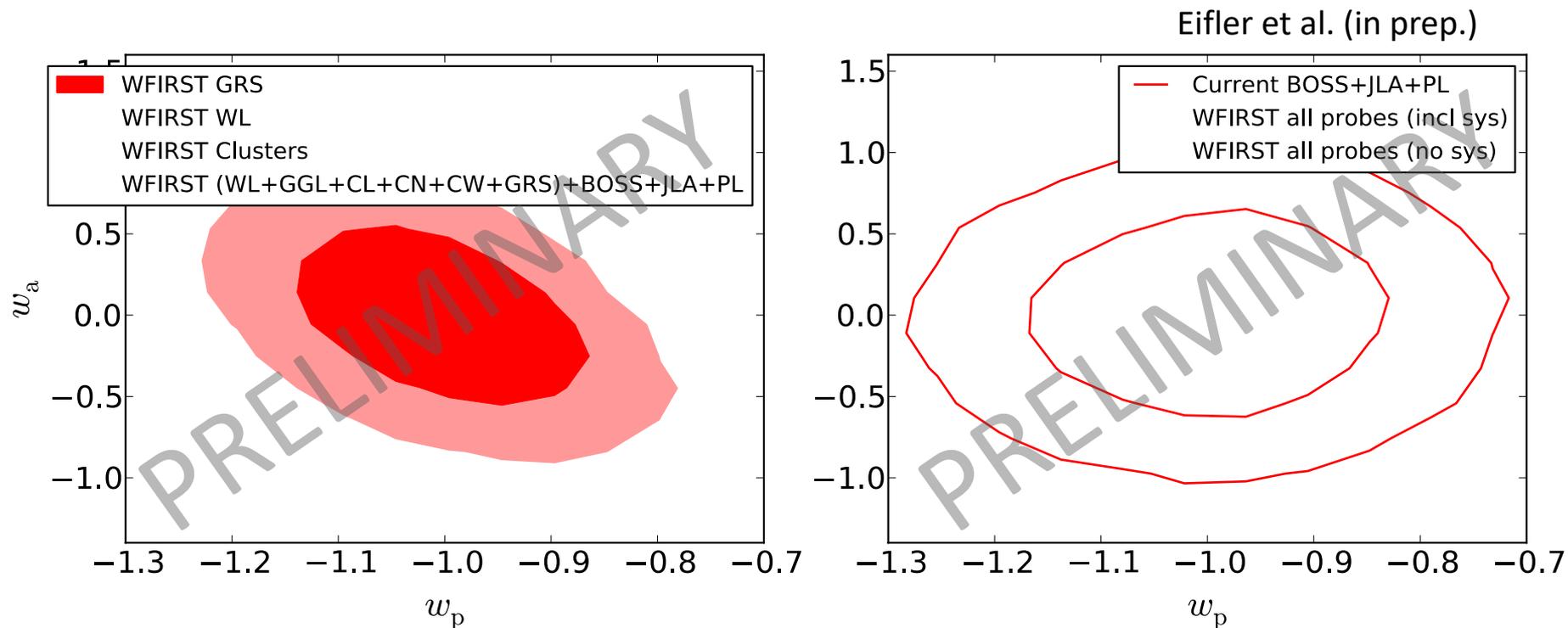
history of dark energy  
+  
deviations from GR

$w(z)$ ,  $\Delta G(z)$ ,  $\Phi_{REL}/\Phi_{NREL}$



Spergel *et al.*  
(2015)

# Multi-probe Cosmology



- Demonstration of power of **multi-probe mission**.
- WFIRST strategy **optimized to address systematics** and maximize robustness of results (c.f. Euclid optimized for statistical precision).

# Stage IV Dark Energy Surveys Comparison

	<b>DESI</b>	<b>Euclid</b>	<b>WFIRST</b>	<b>LSST</b>
Start, duration	2019, 5yr	2021, 6yr	~2025, 5(-10)yr	2022, 10yr
Area (sq. deg.)	14,000 (N)	15,000 (N+S)	2,000 (S)	20,000 (S)
FOV (sq.deg.)	7.9	0.53	0.281	10
Mirror diameter (m)	4	1.3	2.4	6.7
Spectroscopic Survey	Fibers R=2000-5500 0.36-0.98 $\mu\text{m}$	Grism R=250 1.25-1.85 $\mu\text{m}$	Grism R=461 $\lambda$ 1-2 $\mu\text{m}$	
Spectroscopic Galaxies	LRGs + ELGs $z \sim 0.6-1.7$ (20M-30M)	ELGs: $z \sim 0.9-1.8$ (~30M)	ELGs: $z \sim 1-2$ Ha (~20M) $z \sim 2-3$ O[III] (~2M)	
Photometric Survey		4 bands (YJH+VIS)	4 bands (YJH+F184)	6 bands (urgizY)
Photometric Galaxies (/w shapes) (#/arcmin <sup>2</sup> )		~30 in 1 band (VIS)	~45 in 3 bands (YJH)	~30 in 6 bands (ugrizY)
SN1a			2700 $z=0.1-1.5$ IFU spectroscopy	10k-100k/yr $z=0-0.7$ photometric

# Summary

- WFIRST is a **dark energy + exoplanet mission** with **wide-field capabilities**.
- WFIRST is a **2.4m telescope** that will provide **Hubble-like imaging** resolution but over **100x more sky**.
- WFIRST will nominally be a 5yr mission, but can be extended to 10yrs.
- WFIRST **High Latitude Survey** will be optimized for dark energy studies:
  - Nominally 1.5 years over  $\sim 2,000 \text{ deg}^2$ .
  - $\sim 22\text{M}$  ELGs observed with slitless spectroscopy over  $1 < z < 3$ .
  - Shape information for  $\sim 380\text{M}$  galaxies ( $\sim 45 \text{ galaxies/arcmin}^2$ ) in YJH +F184.
  - Designed to be **synergistic with Euclid**.
- WFIRST HLS is designed as **multi-probe mission optimized to address systematics**.
- WFIRST = a **survey** + an **observatory** (25%++ GO) + an **experiment** (tech. demo.)
- WFIRST data will be made public straight away with **NO PROPRIETARY PERIOD**.

[www.wfirst.gsfc.nasa.gov](http://www.wfirst.gsfc.nasa.gov) [www.wfirst-hls-cosmology.org](http://www.wfirst-hls-cosmology.org)